J. Environ. Nanotechnol.
Volume 7, No.4(2018) pp. 60 -64
ISSN (Print): 2279-0748
ISSN (Online): 2319-5541
doi:10.13074/jent.2018.12.184329

Impact of Curing on Mechanical Properties of Concrete-Environmental Approach

Indra Kumar Pandey[1]*, Parah Salsabeel Jalal[2], Ashok K. Tiwari[3], Vikas Srivastava[4]

[1,2,4]Department of civil engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj(U.P.), India.
[3]Vice Precedent-Technical, UltraTech Cement Limited, Lucknow, India.

Received: 19.09.2018 Accepted: 24.11.2018

Abstract

The advancement in construction industry has paved a new way of environmental pollution. These industries produce almost 7% of worldwide production of total carbon di oxide emission. Apart from producing CO2 these industries also consumes a tremendous amount of energy and produce dust, heavy metals, hydrogen chloride, hydrogen fluoride etc. which are hazardous in nature. This paper studies the environmental impact of different curing regimes as well as effects of curing of conditions on the durability (permeability, abrasion resistance and sulphate attack) and mechanical (compressive strength) properties of concrete. Improved durability is important for environmental sustainability of concrete.

Curing is designed primarily to keep concrete moist, by preventing the loss of moisture from the concrete during the period in which it is gaining strength. Curing generally promotes the hydration of cement as a consequence of which hydrated products fill the pores of concrete and produces more compact structure whose permeability is less. As a consequence of reduced permeability water and other harmful chemicals do not enter in the concrete, thus durability is improved. Durable concrete can reduce the total annual concrete production, thus reducing total environmental pollution caused by concrete industry. Curing may be applied is the number of ways and most appropriate method depends on the site conditions and materials used. The behavior of cured concrete in terms of permeability, Sulphate attack, abrasion resistance and compressive strength is studied in this paper.

Keywords: *Abrasion resistance; Curing; Durability; Environmental impact; Permeability; Sulphate attack;*

1. INTRODUCTION

Curing is maintaining sufficient moisture content as well as adequate temperature in concrete for a particular period of time immediately after placing and finishing operations. Curing has a great influence on properties of harden concrete. In order to attain good quality concrete a suitable concrete mix must be followed by curing in a suitable environment during early ages of concrete. Proper curing will increase durability, volume, stability, strength, water tightness, abrasion resistance, and resistance to freezing and thawing. Exposed slab surface are especially sensitive to curing as strength development and freeze-thaw resistance of top surface of slab can be reduced when curing in defective.

A chemical reaction called hydration reaction takes place when cement is mixed with water. The extent of this reaction influences the strength and durability of concrete. In freshly mixed concrete amount of water is much more than that of required for hydration but due to excessive water evaporation the process of hydration may be delayed or stopped. The surface of concrete dries first so it is more susceptible to insufficient hydration.

Curing not only influence the strength but it also influence the durability properties of concrete is much more important concrete industry contribute 7.8% of total carbon dioxide emission in the atmosphere. Concrete production industry is third ranking produces of anthropogenic carbon dioxide in the world. If we improve the durability properties of concrete we can reduce the overconsumption of concrete and also reduce the carbon footprints in environment. Durable concrete experiences a long service life in most natural environments without deterioration. Inadequate curing results a porous and weak structure near the surface of

Indra Kumar Pandey
Email: *indra5973@gmail.com*

concrete that allows the entrance of various harmful substances from the environment.

The curing compounds used in this experiment reduced the water loss compared with no curing. Under hot weather conditions, the effect of curing compound application on moisture retention became much clearer (Wang *et al.* 2002). There was no different in permeability between middle and bottom portions of cores for varying curing condition. For the top portion of the concrete core, the concrete cured with water-based curing compound and wet curing had almost the same values of permeability (Cable *et al.* 2003). All curing compounds decreased the moisture loss when compared to no curing, but none of compounds retained the same or more moisture then plastic sheeting (Whiting and Snyder, 2003).Relative humidity is a prime factor in determination of curing effect of concrete. Compound curing is found to more effective in complex structure (Reddy, 2013). In the research it was found that conventional water curing is most efficient method. It was reported that use of curing compounds resulted in strength up to 85 to 95% by ponding method**.** In acute shortage of water, membrane curing is more useful (Tighare and Singh, 2017).It was evaluated that a double layer membrane curing compound is more effective than single layer. It was also found that double layer of wet jute shows improvement in compressive strength. Pack curing shows 16% improvement in compressive strength then that of air drying (Gowsika *et al.*2017).

Curing improve physical (e.g. freezing and thawing action, permeability, temperature stresses) as well as chemical (e.g. sulphate and chloride attack) durability. Since curing of concrete improves the process of hydration, more hydrated products will form that will fill the voids in concrete. Due to this the permeability of concrete is reduced. Less permeable concrete means the entrance of chemicals and water from outer environment is hindered. As a consequence of that chemical attack and corrosions of reinforcement is reduced.

2. METHODS OF CURING

Ponding and Immersion: Ponding can be done on flat surface of concrete small soil or sand dikes are made around the periphery of concrete surface and water is filled. It is an ideal method to prevent moisture loss from concrete and for maintaining uniform temperature in the concrete. The temperature of curing water should not be more then 11°C cooler than that of concrete to avoid thermal stresses that may cause cracking. Ponding requires considerable supervision and labor therefore it is suitable for small jobs.

The method of immersion is generally used in laboratory for curing test specimens. In this method test specimens are completely immersed in water. Although Ponding and immersion is the most efficient method but it requires considerable amount of potable water for curing of concrete which leads to severe pollution of fresh water. Therefore in context of short term environmental pollution this method is not appropriate but in long term prospective since this method produces a durable concrete so it is convenient to adopt this method. In short term it only pollutes the water but it also helps to reduce the production of carbon footprints by increasing the durability of concrete in long term prospective.

Fogging and Sprinkling: When the ambient temperature is well is well above freezing and humidity in low, fogging and sprinkling is excellent method of curing. A system of nozzles or sprayers is used to create a fog mist to raise relative humidity of the air. Fogging is used to minimize the plastic shrinkage cracking. Proper water supply and careful supervision is must for this method. If sprinkling is done at intervals concrete must be prevented from drying by using some water absorbing materials such as burlaps.

In this method energy consumption of energy is involved to operate nozzles and sprayers. For energy production burning of fuels comes in picture which leads to air pollution. Apart from polluting air up to a minor extent, this method causes a tremendous water runoff which leads to wastage of water.

Wet Covering: Fabrics saturated with water are used for cursing e.g. burlaps, cotton mats, rugs etc. For vertical surface wet gunny bags, hessian cloth, jute ratting etc. are used to keep concrete in wet condition. For horizontal surface, saw dust, earth or sand are used for wetting the concrete. Care must be taken to avoid drying of these coverings otherwise they will suck the moisture from concrete by capillary action.

Since there is no surface runoff of water in this method so it is a convenient for minimizing the water pollution. This method also gives good results in terms of durability.

Impervious Paper: It is an efficient means of curing horizontal surface and simple shaped concrete. Periodic addition of water is not required in this method. Impervious paper retains the internal moisture of concrete and thus promotes the hydration. When concrete is sufficiently hardened to resist surface damage, it is thoroughly wetted and impervious paper is applied. The edges of these papers should be properly sealed and adjacent sheets are sufficiently overlapped (about 150mm).

Directly use of impervious paper does not cause any kind of environmental pollution but the production

units of these papers is a potential source of environmental pollution. In production unit heavy water pollution, huge energy consumption, emission of harmful gases is very prominent factors that can cause heavy pollution.

Plastic sheets: Plastic sheets such as polythene films can be used for curing purpose. They are light weight, effective moisture retarder and they can be easily applied on flat on complex surface. Curing with plastic sheets may cause patchy discoloration. Plastic sheets are major source of environmental pollution as they are not decomposable after their use. It is effective in reducing the water pollution but on the other hand they cause much serious environmental problems.

Membrane Forming Curing Compound: Liquid membrane forming compounds can be used as evaporation retarder from concrete. These compounds may contain waxes, resins, chlorinated rubber etc. Curing compounds are able to maintain the relative humidity of concrete surface above 80% for seven days to promote cement hydration. These compounds should be applied by hand operated on power driven spray immediately after final finishing of concrete. Normally only one smooth coat is applied at the rate of 3 to 4 m^2 per liter or as per manufactures instruction.

These compounds are used to eliminate the compulsion of water for curing. They form a protective layer over the surface to skip the evaporation of water inside of concrete. Since these compounds are sprayed in air, they contribute in air pollution up to some extent.

Steam Curing at Ordinary Pressure: When the early strength gain the concrete is important on where additional heat is required to accomplish hydration, steam curing can be used. This method is generally used for prefabricated members. This method is quite difficult to apply on site. Hydration reaction is accelerated at higher temperature and concrete attains the 28 days strength in only 3 days.

Steam Curing at High Pressure: In this method of curing concrete is subjected to a maximum temperature of about 175°C which gives a steam pressure of about 8.5 kg/cm^2. Concrete subjected to high steam curing contain 20 to 30% pozzolanic material such as crushed stone dust, it is observed that concrete with higher water/cement ratio. One of the main advantages of steam curved concrete exhibits higher resistance to sulphate attack, freezing and thawing action and chemical action. It also shows less efflorescence.

Steam curing at high pressure as well as ordinary pressure requires tremendous amount of energy to producing steam and creating pressure so it could be said that certain environmental pollution might be seen. But whenever early strength of concrete is required these methods are most convenient.

Electrical Curing: This method of curing is generally used in very cold climatic regions. Due to economic reasons this methods is not used in normal conditions. Concrete is cured electrically by passing an alternating current through the concrete between two electrodes either buried in concrete or applied to the surface of concrete.

This method of curing requires electricity of high voltage. So on construction site there is zero environmental pollution but in electricity generation point is a effective environmental polluting site.

Forms Left In Place: If top exposed surface are continuously wet than form provide a satisfactory protection against the loss of moisture. The forms should be left on the concrete as long as possible. If wooden forms are used, they should be kept moist by sprinkling water during hot weather. If it is not possible, they should be removed as soon as possible to avoid the moisture suction from concrete.

This method generally causes zero environmental pollution since no burning of fossil fuels and minimal amount of water is needed for the purpose of curing.

2.1 Effect of curing on compressive strength

Cement needs a certain level of relative humidity to continue to hydrate. Even though different values are reported for the cement hydration to continue, 80 percent is the widely accepted relative humidity value. If the relative humidity in concrete pores falls below this value, the hydration of cement virtually stops and further improvement of concrete properties owing to continued cement hydration and pore filling by hydration products is not achieved. The compressive strength of concrete is function of various parameters, one of which is the length of time for which it is cured. Various studies shows that concrete without curing achieves only 40 to 45% of compressive strength of the same concrete which is cured. Even 3 days water curing increases this figure to 60 to 65%, while 28 days curing increase it up to 95 to 98%. So curing improves the compressive strength in an effective manner. Concrete that is allowed to dry out quickly also undergoes considerable early age drying shrinkage

2.2 Effect of curing on Abrasion Resistance

Concrete roadways, industrial flooring and other public accessible areas are subjected to high abrasion conditions. So it is important to improve the abrasion

resistance of such type of surfaces. Since curing improves the surface characteristics so abrasion resistance may be an effective parameter to evaluate curing effectiveness. Abrasion resistance of hydrated cement is lower than that of aggregates, particularly porous cement matrix. The porosity of the concrete can be reduced by providing effective curing by an efficient method. Abrasion resistance is much more of cured concrete than that of uncured concrete. Studies show that ponding is most convenient method to improve the abrasion resistance since it reduces the porosity of concrete by promoting the process of hydration. Inadequate or insufficient curing is one of main factors contributing to weak, powdery surfaces with low abrasion resistance.

2.3 Effect of curing on durability of concrete

Durability can be defined as the capability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. Durability can be classified into two heads. One its physical durability and another is chemical durability. As we discussed earlier, curing of concrete promotes the hydration reaction of Portland cement and enhance the quality of hydrated products. These hydrated products fill the pores of concrete and improve its strength and durability properties. The durability of concrete is affected by a number of factors such as porosity, permeability and absorptivity. Well cured concrete can minimize thermal, plastic and drying, shrinkage crakes, making concrete more water tight, thus preventing the entry of moisture and water brone chemicals into the concrete and thereby increasing its durability.

Curing promotes the steady hydration reaction to produce Calcium Silicate hydrated gel, which binds the aggregate and increases the density of concrete, decreases the porosity and enhance the chemical and physical durability of concrete.

2.4 Water Permeability

Permeability of concrete is defined as the rate of flow of fluid into a porous solid. The permeability of concrete is a major factor that affects the long-term durability of concrete as it controls the movement of water and entry of aggressive liquids. Curing improves the process of hydration as a consequence of which pores of the concrete is filled with hydrated products. The filling of pores and disturbing the capillary fringes in the concrete improves the permeability. Studies show that coefficient of permeability continuous to reduce with concrete age. This is because of hydration of cement particles over a long span of time. It is generally not that porosity but pore structure and presence of micro cracks are crucial in determination of permeability of concrete. These micro cracks will propagate on the application of load and reduce the durability of concrete.

2.5 Sulphate attack

Sulphate attack may cause excessive expansion, cracking and loss of strength. The degree Sulphate attack depends of water penetration, the Sulphate Salt and its concentration and type of salt (e.g. Calcium or Magnesium). In presence of Calcium hydroxide, formed as a hydrated product, Sulphate ions will react to produce ettringite. These ettringite crystals expand or swell and cause volumetric changes in concrete mass. Due to these volumetric changes concrete that is subjected to sulphate attack pronounce some cracks which reduce the durability of concrete. By proper means of curing more compact and dense structure is produced which reduces the penetration of Sulphate Salt thus increasing the durability of concrete. The compressive strength of concrete is reduced when it is subjective to Sulphate attack because of presence of cracks.

3. CONCLUSION

Ponding and immersion are most efficient method for curing the concrete as they attain almost 95 to 98% strength but their water demand is more. Membrane curing compounds are effective tool where water is in scarcity. In very cold climate electrical curing is effective but in normal weather it is not used because of the matter of cost. Curing with wet covering are most appropriate method when we talk about reducing the environmental pollution because these bags are biodegradable and requires comparatively less water and produce more durable concrete. It was observed in this study that uncured concrete produce only 40 to 45% of compressive strength than that continuously cured concrete. It is also noted that uncured concrete is more favorite spot for sulphate attack to produce crack and reduce the strength of concrete.

Curing generally improves the surface behavior of concrete so it is noted that abrasion resistance of cured concrete is much more than that of cured concrete.

It is also noted that the permeability of concrete is also dependent on curing of concrete. The coefficient of permeability is reduced with increase in curing period. This is because of formation of good quality of hydrated products that fill the voids of concrete and discontinue the capillaries in the concrete. Overall we can say that curing methods cause some environmental

pollution in short time span but if we look at long term behavior than curing not only improves durability but also reduces the pollution caused by concrete industries.

REFERENCES

Abalaka, A.E. & Okoli, "Influence of curing regime on strength development of grade C60 concrete", International Journal of Modern Engineering Research (IJMER), Vol.3, Issue.2, March-April,2013, pp-709-714.

ACI Committee 305, "Hot-Weather Concreting", ACI 305R-99, American Concrete Institute, Farmington Hills, Michigan, 1999, pp 17.

ACI Committee 306, "Cold-Weather Concreting", ACI 306R-88, Reapproved 1997, American Concrete Institute, Farmington Hills, Michigan, 1997,pp23.

ACI Committee 308, "Standard Practice for Curing Concrete", ACI 308-92, Reapproved 1997, American Concrete Institute, Farmington Hills, Michigan, 1997, pp11.

ACI Committee 330, "Guide for Design and Construction of Concrete Parking Lots", ACI 330R-92, Reapproved 1997, American Concrete Institute, Farmington Hills, Michigan, 1997, pp27.

ACI Committee 362, "Guide for the Design of Durable Parking Structures", ACI 362.1R-97, American Concrete Institute, Farmington Hills, Michigan, 1997, pp 40.

ACI Committee 516, "High Pressure Steam Curing: Modern Practice and Properties of Autoclaved Products," Proceedings of the American Concrete Institute, American Concrete Institute, Farmington Hills, Michigan, August 1995, pp 869 to 908.

ACI Committee 517, "Accelerated Curing of Concrete at Atmospheric Pressure", ACI 517.2R-87, revised 1992, American Concrete Institute, Farmington Hills, Michigan, 1992, pp 17.

Burg, Ronald G., "The Influence of Casting and Curing Temperature on the Properties of Fresh and Hardened Concrete", Research and Development Bulletin RD113, Portland cement Association, 1996, pp 20.

Greening, N. R., and Landgren, "Surface Discoloration of Concrete Flatwork", Research Department Bulletin RX203, Portland Cement Association, http://www.portcement,1966, pp 19.

Gonnerman, H. F. and Shuman, E. C., "Flexure and Tension Tests of Plain Concrete," Major Series 171, 209, and 210, Report of the Director of Research, Portland Cement Association, November 1928, pp 149 and 163.

Kosmatka, S.H. Panarese, "Design and Control of Concrete Mixtures". Skokie, IL, USA: Portland cements Association, 1965, Pp 17, 42, 70 and 184.

Krishna Rao, M V, Rathish Kumar, Azhar Khan, "A study on the influence of curing on the strength of a standard grade concrete mix", Architecture and Civil Engineering, Vol. 8, No 1, pp. 23 – 34.

Senbetta, Ephraim, "Curing and Curing Materials," Significance of Tests and Properties of Concrete and Concrete-Making Materials, STP 169C, American Society for Testing and Materials, West Conshohocken, Pennsylvania, 1994, pp 478 to 483.

Verbeck, George J., and Helmuth, R. A., "Structures and Physical Properties of Cement Pastes," Proceedings, Fifth International Symposium on the Chemistry of Cement, vol. III, The Cement Association of Japan, Tokyo, 1968, pp 9.

Zain, M.F.M "Effect of different Curing Methods on the Properties of Micro Silica Concrete". Australian Journal of Basic and Applied Science, May, 2007, pp87 – 95.